Howard Rush

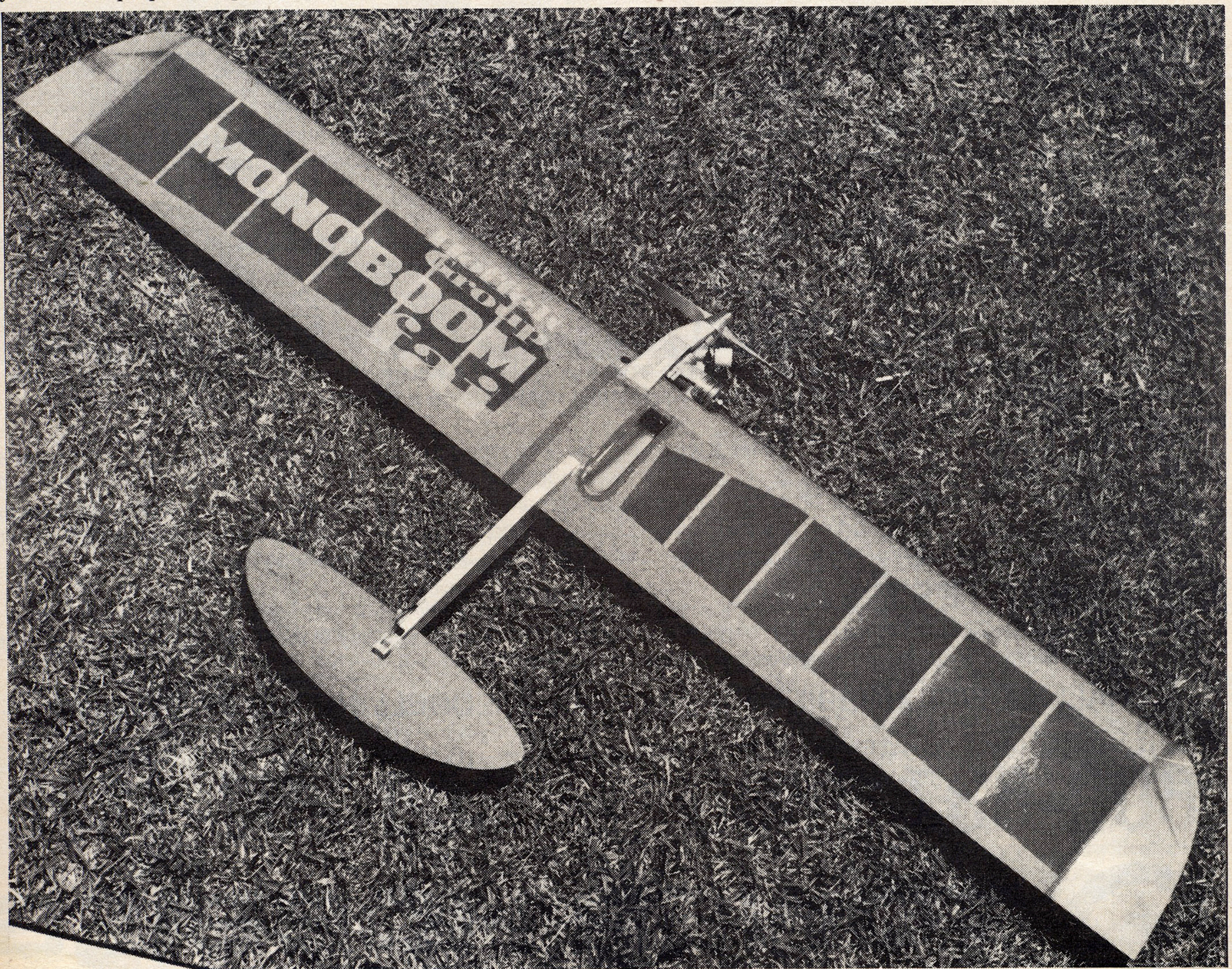
Trends in Combat Design

A new wave of airplanes is shaking up the combat fliers' world. Will simplicity win out? Or will the challenge of potent exotic designs affect the picture during the next one or two seasons? Here is an unopinionated analysis of what is going on.

Editor's Note: Like many modelers with different interests, your editor has—we now should say "had"—an oversimplified picture of what makes the combat flier tick. Mr. Rush's article is a long overdue exposition of the serious and scientific side of an impressive event. We urge everyone to read this feature—it is an eye-opener. And for Combat people, it a perceptive, valuable report on the state of the art.

THE dominant trend in control line Combat airplane design is toward airplanes that are easier and cheaper to build. The hard part, of course, is to make cheap, easy-to-build airplanes that are competitive. New materials, new techniques, and refinements of old techniques are making simple planes competitive.

Structural Techniques: From Carl Berryman's Twister in 1958 until recently, most Combat planes were built around a box formed by two heavy balsa wing ribs about six inches apart, the wing LE and TE, and 1/16 sheet balsa on the top and bottom surfaces. The box served to distribute loads



Prime example of the "exotic" approach in Combat design is Mike Hoffelt's FAI Monoboom. It is distinguished by a very high aspect ratio wing, and is cleaned up by having controls located internally. Of special interest is its use of the exhaust duct on top of right wing.

from the engine, which was mounted on beams attached to more structure in the box's center. The bellcrank was supported by the rib on the left side of the box and a metal fuel tank was nestled between the engine mounts and the rib on the right side of the box. The ribs also carried loads from two tail booms, which supported a stabilator.

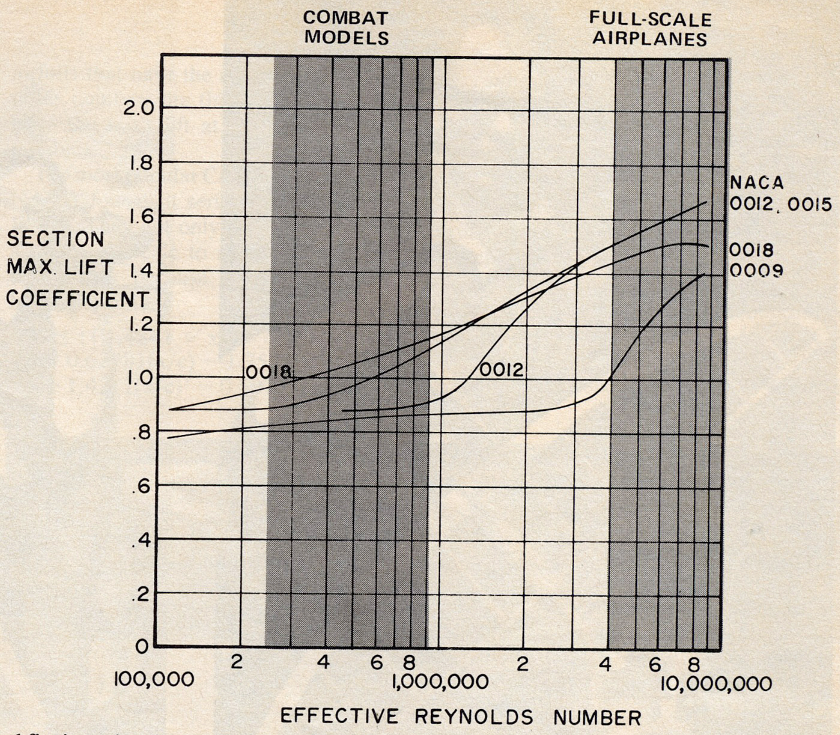
About 12 years ago, pen-bladder and baby-pacifier fuel systems replaced metal tanks. Then, inspired by John Kilsdonk, we began attaching the bellcrank mount to the engine mounts. Clever people in Detroit and Cincinnati saw that the box structure, which now served only to carry engine and tail boom loads, could be replaced by a structurally more efficient single fuselage.

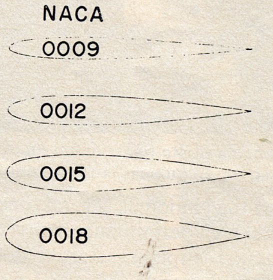
Although the single-boom structure took ten years to catch on, it has been adopted almost universally by U.S. Combat fliers in the last year or so. Builders have come up with structures that are simple and light, yet strong enough to withstand the rigors of Combat.

Lots of reinforcement is required at the stabilator hinge to keep the tail from breaking off when it snags the grass or the launcher's leg. Hinges are usually music wire and brass tubing, reinforced with plywood, cloth and epoxy. I like Phil Cartier's method—a Rocket City nylon strip hinge with the front half imbedded in a ½ × 3 plywood stabilizer.

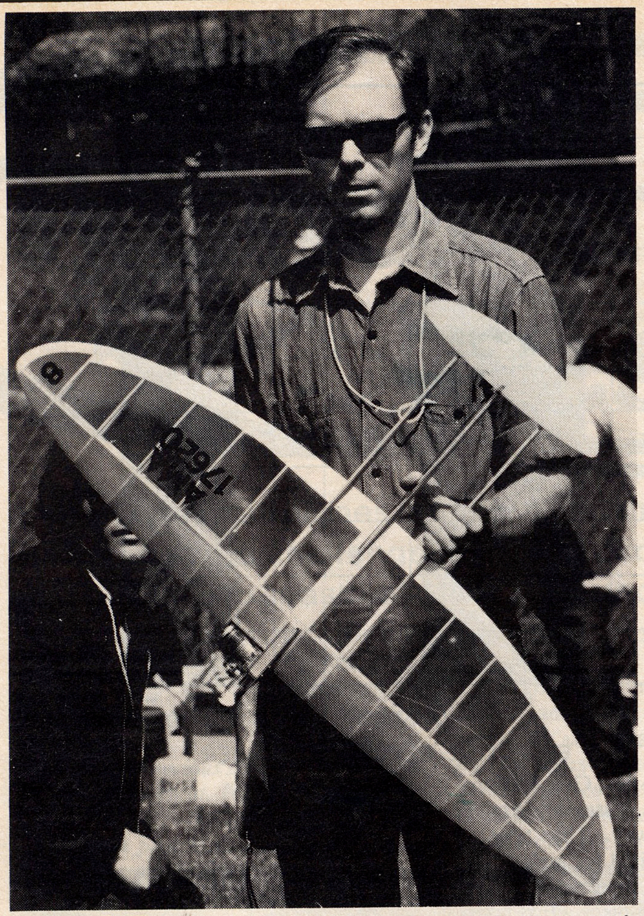
Another time-saving construction trick is the one-piece TE. This method uses one ⅛ TE sheet, rather than two sheets of 1/16 wood with a tedious-to-cut chamfered joint. The one-piece TE is sharpened at the rear and fits into slots in the ribs. Gussets make the rib-TE joints sturdy. Assembly is much easier than the old way. This type of construction is well-suited for airfoils like Wortmann's which are concave and quite thin at the TE. The one-piece TE is warp-prone, so use hard wood.

The single-boom concept and film covering materials have made plastic foam airplanes practical. Foam airplanes have been around a long time. Riley Wooten's Vam-





The author's Nemesis II took the top three places in Open Combat at the 1973 Nationals. It has since been replaced by simpler, better-performing airplanes. Left to right: Ron Esman, third; Max Mearns, second, and Mark Pattie, first.



Steve Sacco's Bosta has molded fiberglass leading edge that extends back to spars. Elliptical planform requires lots of building effort.

Chuck Rudner's conventional airplane is one of the best. He flew similar airplanes at the 1978 Control Line World Championships.

pire won the Nationals several times since 1966, but high-performance, conventional-construction airplanes started doing the winning in the early '70s, and we forgot about foam. Gary James, Chuck Thomas, Phil Cartier, Riley Wooten, and others have developed foam airplanes in the last few years that are quite competitive with standard airplanes. Richard Brasher's foam Rotation Station is the best Combat plane I have flown, regardless of construction.

These new foamies have in common a single fuselage; a hot-wire-cut, tapered wing covered with plastic film; and a wing structure of little more than a spar at the airfoil's maximum thickness point. They have no LE structure, because plastic film-covered foam catches kill-zone strings. When your wing passes through your opponent's kill zone, the string cuts into your LE and breaks.

Foam planes tend to be heavy. The new foamies weigh about 20 oz. with everything but fuel, compared to 17 oz. for a good wooden plane. Foam fliers forsake crash survivability to keep weight down, except Brasher, whose airplanes weigh about 23 oz. and are sturdy enough to withstand some turf encounters.

Materials: The biggest recent revolution in Combat planes is in materials. Plastic foam is the most revolutionary material. The most popular type of foam for Combat plane construction is one lb./cubic ft.-beaded polystyrene, sold primarily for

Rush's modification of Gary James' foamy has long tail for maneuvering stability and forward sweep for upwind performance. Joanne Bartley is the better-looking model, however.

Gene Pape looks unhappy, but his airplane is the best around. A built-up copy of Rich Brasher's foam Rotation Station, it needs extra spars on the left wing to prevent roll instability.

building insulation. This foam is available in densities up to five lb./cubic ft. Strength-to-weight ratio doesn't change much with density. The denser stuff has a smoother surface when cut, but it requires the wings to be hollowed out to keep weight reasonable.

Full-scale airplane builders prefer extruded polystyrene foam, such as Dow's Styrofoam. Some British fliers are using extruded foam, but I haven't seen it in U.S. Combat planes.

Glass fiber-reinforced resin is old hat. We've been using it to reinforce engine mounts for years. But people are now doing amazing things with glass and more exotic composites.

Steve Sacco molds the entire front quarter of his wings out of glass-reinforced polyester. He gets a smooth, true airfoil with less effort than for a wooden structure.

FAI Team Race fliers are building fuselage shells out of epoxy reinforced with carbon fiber mat. It is very light and is stiff enough for Combat wings. Carbon-reinforced epoxy is several times stronger and much stiffer than glass composites of the same weight. Carbon fiber is expensive, $90 for a yard of cloth, but the price is coming down because of production volume and new manufacturing processes. Bundles of carbon fiber strands are available from the National Free Flight Society for 30¢ per meter. They make a good spar reinforcement when imbedded in epoxy on wood spars.

Kevlar, a DuPont synthetic fiber, is almost as strong as carbon fiber. It is used to make bullet-proof vests. It is cheaper than carbon—about $10 per yard for cloth. Former U.S. FF Power team member Charlie Martin builds the front ends of his beautiful FAI planes from Kevlar-reinforced epoxy. The same technique can be used for Combat planes.

I was one of the last to give up silk and dope, but I don't regret it. The plastic film covering materials sure make things easy. The favorite among Combat fliers is FasCal, a clear, adhesive-backed polyester graphic arts film made by Fasson Products. It doesn't come in pretty colors, but it is light, cheap, and strong. It sticks to foam, although you must take it easy with the heat. My favorite films are Pactra's low-temperature SolarFilm for foam and Top Flite's Super MonoKote for wood. They are pretty and cooperative to work with.

The new polyurethane paints are a welcome replacement for "hot fuel proof" dope, which is soluble in nitromethane. Polyurethane sticks to film covering material better than epoxy paint and it won't melt foam.

Airfoils: The shape of a Combat plane's wing section (airfoil) has a big effect on its performance. Picking the best airfoil is mostly trial and error. Published data aren't much help because they're intended for "real" airplanes. The best airfoil for our Reynolds number range is not the best for a full-scale airplane. Fig. 1 shows that the airfoils that have the most lift at our Reynolds numbers are thicker than those that have the most lift at full-scale Reynolds numbers.

The most popular Combat airfoils are the NACA four-digit series, developed in the 1930s. They not only work well, but they are easy to scale to different chords and thicknesses because they come from a handy formula:

$$Y = \pm t[1.4841\sqrt{x/c} - 0.62981(x/c) - 1.7575(x/c)^2 + 1.4211(x/c)^3 - 0.50735(x/c)^4]$$

. . . .where t is the maximum thickness in inches, X is the distance along the chord in inches, C is the chord in inches, and Y is the distance above and below the airfoil mean line in inches. The mean line is a straight line between the LE and TE. These calculations are easy with a programmable calculator. Better yet is a computer plotter to draw your ribs.

Modified NACA airfoils abound. The Nemesis II and Bosta use a 16.5% NACA four-digit section with the maximum-thickness point squished forward to 25% chord.

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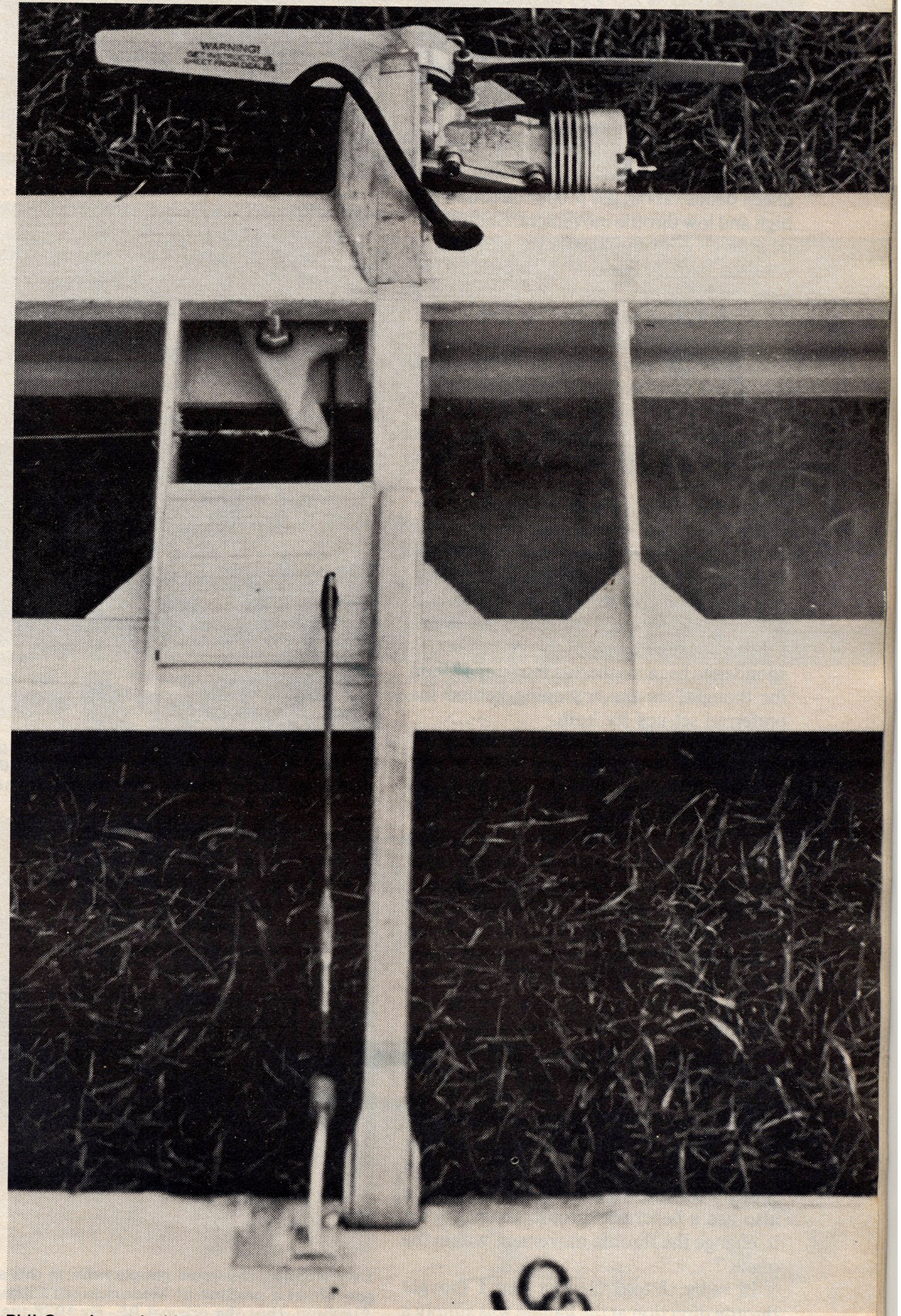

Phil Granderson's 1978 Nationals winner illustrates single boom, one-piece trailing edge and reinforced stabilizer hinge. Phil's plane is elegant in its simplicity.

Champs and the models flown in that sort of competition. But there is considerable material on the Indoor World Champs and Coupe d'Hiver, and even a smattering of Old-Timer modeling and Free Flight, U.S.-style as exemplified by the U.S. Free Flight Champs. There are sections about the developments and techniques associated with each model class written by some of the most knowledgable fliers in the business. There are blow-by-blow accounts of all of the major international and World Champ competitions in the period covered, and complete listings of the results.

The full-page plans occupy about half of the book. Each is accompanied with a story about the history and development of the model in the modeler's own words. About 90% of the plans have appeared in publications available to U.S. FAI fliers—Scatter, Free Flight News, the NFFS Digest, Indoor News and Views, and so forth—but it is nice having them all under one cover. Most of the color photos are truly excellent, but I could have been perfectly happy without the postcard shots of l'Arc de Triumph and le Tour Eiffel, and some of the family-album type snapshots. Nevertheless, on the whole the photos document the spirit of international free flight competition—its triumphs and tragedies, glories and defeats, and the pure fun of it—in addition to its technology.

It is a book any red-blooded American FAI-oriented free flighter would be proud to own.

Announcement: Fresno Annual. The September 29-30 weekend will see the fortieth consecutive annual contest put on by the Fresno Gas Model Airplane Club. Events will include the three FAI events, 1/2A, A, B, C, and D Gas, Coupe, P-30, Mulvihill, A-1 Glider, Hand Launch Glider, and perhaps a few others. The Stockton club's Old-timer Meet will be held simultaneously at the same site. Last year's annual drew 155 contestants, and there was more than $2,200 worth of prizes, including engraved, silver-plate bowls for the sweepstakes winners; this year's meet promises to be bigger and better in every respect. The site is on sheep-grazing land, 1 × 1½ miles, and criss-crossed with paved roads at quarter-mile intervals. Motorcycles are OK. Contact man is Russ James, 4840 E. Leisure, Fresno, CA 93727. Call (209) 255–2422 anytime.

Also something new for the Fresno club will be a series of Indoor meets, the first of which will be on June 23. Check with Russ for the details.

Bob Meuser, 4200 Gregory St., Oakland, CA 94619.

Combat Trends/Rush

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Gary James and Steve Sacco have modified the NACA formula to change such things as the LE radius and TE angle.

The best airfoil to use depends also on the wing surface bumpiness. Surface imperfections near the LE really degrade the Nemesis II airfoil's performance, but the foamies get away with their bumpy surfaces by using really blunt LEs. I'm using a Gary James-modified NACA airfoil with a fat LE on my foamy and it works great.

New airfoil design techniques have been developed in the last few years that may make airfoil design scientific and spoil our fun. These techniques consist of determining what pressure distribution you want and then calculating the shape that gives it to you.

F.X. Wortmann, at the University of Stuttgart, has designed some of these new-fangled airfoils for full-scale sailplane tail surfaces that operate at the same Reynolds numbers and design conditions as Combat models. His wind tunnel data show improvement over the old NACA airfoils, but Combat fliers have shown little interest in trying the new sections—probably because they look so different. They have pretty sharp LEs and are concave near the TE. Want to be the first kid on your block to try one? They are in *Stuttgarter Profilkatalog I,* by D. Althaus, published by the Institute für Aero-u Gasdynamik, University of Stuttgart, Germany, 1972.

Configuration: Airplanes are bigger now. There are several reasons why.

Combat planes must turn tight, fast loops. The minimum loop diameter an airplane can turn is proportional to its wing area loading (if other factors don't change). Area loading is the ratio of weight to wing area. The speed an airplane can maintain in consecutive maneuvers depends on its induced drag. For a given loop size and speed, induced drag is proportional to the square of the span loading. Span loading is the ratio of weight to wingspan.

Foamies need lots of wing area and span to make up for the foam's weight disadvantage. Because engine, fuel, and line weight are constant, you get a lower area loading and span loading by going to a bigger, longer wing. AMA-class foamies typically have 42″ to 48″ spans and 360 to 400 sq. in. areas, compared to 39″ spans and 320 to 360 sq. in. areas for conventional planes.

Conventional-construction airplanes have practical wing span limits. Balsa comes in 36″ lengths. More span means buying more-expensive 48″ wood. It is also harder to keep warps out of longer wings.

Sherwood Buckstaff and his Texan colleagues kept to 36″ span, but increased chord to 10″—an inch more than the standard planes of the time—and gained an area loading advantage over us. They paid for the area with increased drag, but they made up for the drag with honkin' engines. The rest of us went to bigger airplanes to avoid being outmaneuvered by the Texans.

FAI airplanes have also grown in the past few years. This growth is partly because our first FAI planes were too small (about 230 sq. in.), and partly because FAI engines have increased in power and weight. The Cox Conquest .15, for example, weighs 6 oz., 50% more than the .15s of ten years ago. The new Cox, Fox, and Rossi .15s are so powerful that many fliers use the same size planes for FAI as for the AMA (.36 cu. in.) class. FAI models in Europe are even bigger; most have over 400 sq. in. area.

Tapered wing planforms are gaining popularity. Most foam wings are tapered because taper is free. It's just as easy to make two templates different sizes as it is to make them the same size. Some people—notably Chuck Rudner and Neal White—have gone to the effort of making tapered or elliptical, balsa airplanes.

Tapered wings are structurally nice. There is less air load at the tips and the spars can be spaced farther apart at the wing root. Thus, less spar material is needed to keep the wing from folding.

They also have nice aerodynamic properties. Tapered wings have a little less induced drag than rectangular wings with the same span loading. They are also less affected by wind.

Flat, rectangular-planform wings act as if they have positive dihedral (negative rolling moment due to sideslip) in inside loops and negative dihedral (positive rolling moment due to sideslip) in outside loops. This causes the airplane to fly differently on the upwind side of the circle than it does on the downwind side. Wing taper reduces the dihedral effect. Adding some forward sweep can eliminate it. I have built some tapered, swept-forward wings that fly as nicely upwind as downwind. When I get the bugs out of them, I'm going to be really fearsome on a windy day. You've been warned.

Some tapered wings have a strange property that's not so nice. Because the leadout wires exit the wingtip near the TE, they can twist the wing when it's banked. If the airplane banks to the right due to a wind gust, for example, the lines pull down on the left TE, twisting the wing so that it rolls more to the right. This effect is unstable above a certain speed. The result is a sudden, violent roll that can destroy the airplane. People who have had this problem have usually been able to fix it by stiffening the left wing.

The new wave of simple airplanes is a boon to Combat. If the simple planes remain competitive, we can continue to enjoy the sport with less time at the workbench. A few zealots, though, are challenging the simplicity trend with some really complicated designs. Mike Hoffelt of California (of course) has an exotic FAI airplane that is claimed to turn five-foot diameter loops. Gene Pape of Oregon terrorized everybody (and killed Buckstaff) at the 1978 Nats with a balsa version of

Holding Phil Cartier's Gotcha is Gil Reedy. Phil's foamies are the simplest and among the best flying. His FAI planes, flown by Gary Frost at the 1978 World Champs, wowed the Europeans.

Brasher's Rotation Station.

Are the exotic planes worth the effort? The next season or two will determine which way Combat design will go.

CL Scale/Gretz
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small point of personal preference. In fact, I believe that a person could become just as proficient with either mode of operation and learn either just as easily. I then got into some of my own specific reasons for preferring to fly Scale with high throttle as forward at the handle. I said, in part, "When I set up my first 3-line system years ago, it became obvious that, if I mounted my inverted bellcrank inverted, as it was seemingly intended, with almost any engine the high throttle position would be forward at the control handle's throttle lever. The same holds true for mounting an upright bellcrank upright. All throttle-equipped engines that I know of require the throttle pushrod to move forward to open the carburetor, except for Fox engines which often have a lever for both directions. In other words, when a modeler uses stock equipment and mounts it as the manufacturer intended it to be mounted, he would in almost all cases get high throttle by moving the handles lever *forward.* And this is the way I had noticed most Scale fliers doing it at the Nationals.

"In order to make the system work any other way, you must reverse directions somewhere along the line. As you said, you can incorporate a straight reversing bellcrank arm between the engine and the 3-line bellcrank. Or you can mount an inverted style bellcrank upright or an upright style bellcrank inverted (although I know of some control rod hookup problems here). You can also simply loosen the throttle arm on most engines and rotate it 180 degrees to the top side of the carb. But I couldn't see any possible advantage in Scale flying from doing any of these things. You mentioned that it seemed more natural to you to pull back on the handle's trigger to get fast throttle. But, to me, it seems more natural for fast throttle to be forward as it is in a full-size airplane or an automobile.

"I use my left hand to operate the lever on top of the handle and thus always fly with both hands. Perhaps this is the real heart of our personal preferences in this matter. I'm wondering if you, and other Carrier fliers, normally fly with only one hand, using you index finger to operate the trigger? I feel that, my way, I can operate the throttle more precisely through *all* stages of the scale flight. In competition Scale flying a good share of our point-getting maneuvers are done at or very near low throttle—like the initial takeoff run, landing, touch-and-go, and taxi. During these maneuvers, where precise coordinated elevator and throttle use is most important, I prefer the trigger to be back in what you seem to agree is a more comfortable position."

The day after I had mailed that reply a letter arrived from *MA's* own Carrier expert, and my respected friend, Dick Perry. He very knowledgeably shed some light on why the Carrier fliers prefer their control set-up opposite of what is normal for Scale. Dick said, "It looks like we disagree a little on which way is appropriate direction for open throttle on a 3-line system. It's certainly no big thing! Carrier requirements are just a little different from Scale. Your way—forward is open—is the way the real airplane builders do it, and it works great for two-handed flying—the way most Scale fliers I've seen do it.

"Carrier fliers are a little different. We are generally one-handed with a few exceptions (you can fly a bigger circle on low speed with one hand). We use two hands on high speed, but the left hand is there for support only—the right index finger still handles the throttle; and with 50–75 lbs. pull a pull-to-open throttle is much easier to keep open than a push-to-open rig. With one-hand operation, low-speed throttle action is also more natural when back pressure opens the throttle as up is applied. Also, if properly rigged, an up elevator condition (against the stop or with lines really loose) will automatically open the throttle. Not a bad situation when the total airplane pull is about two pounds!"

So there you have it, the full story! Two different methods for two unique events. As you can see, we could go on and on with a meaningless debate about the merits of this or that method, but let's just conclude that a devoted pilot can get satisfactory results either way. You know, for years RC has had its Mode I (throttle on the right stick) and Mode II (throttle on the left stick) fliers and their tongue-in-cheek word-war about which is best. Perhaps we should divide up into the "two-fisted lever pilots" and the "one-handed trigger pilots." Are we that crazy?

Mike Gretz, Box 162, Montezuma, IA 50171.

CL Aerobatics/Paul
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the engine catches. After the plane is in the air, fly it at eye level, approximately five feet off the ground. Have your spotter (more than one is better) look to see if the outboard wing is up, down, or level. Have the spotter stand downwind facing at you so he can see the plane coming and going. Then have the spotter move counterclockwise 90 degrees around the circle, so he can watch the plane from the downwind side to the upwind side. Spot the plane coming and going from this position, looking for the high or low wing. At this time, the pilot can look for excessive yaw by observing the landing gear. If the inboard gear looks to be in front of the outboard gear as the plane goes around the circle, then there might be too much line rake or engine offset.

Going into inverted flight the first time with a new plane is always a thrill for me, even when I know that the engine and tank setup worked perfectly in the last plane yesterday. I always do a couple of large inside loops first (downwind), and then try an elongated, round inside loop with a long inverted part at the top. Then (what the heck!) I go from the start of an inside loop into inverted flight. Now, get your spotter again to check the wing for high or low outboard tip.

If something seems wrong, then try level upright flight again, followed by inverted flight, right away, to get the spotter's feelings. Since you can't stop now, anyway, and unless the plane is flying so badly that further experiments would be dangerous, then let's go to a series of climbs and dives. The purpose of this is to see if the plane appears to be nose-heavy or tail-heavy *for your style of flying.* If the plane climbs and dives very easily, or with a jerk, it may be tail-heavy and require nose weight. If the plane seems to be locked into a groove on level flight, you probably have too much nose weight.

You may also experience "hunting" in level flight. This means that the ship wants to climb or dive gradually all the time, and you have to keep minutely adjusting the handle to keep the plane in level flight. It seems to have a mind all its own during level flight, and you have to keep adjusting your wrist/hand/handle to maintain constant altitude. To quote the Olympic Mark VI man, Bob Gialdini, "Old stunt planes don't hunt." Why is this, you ask? It's because of *slop.* That is, slop in the elevator movement with